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DOE Project on Heavy Vehicle Aerodynamic Drag

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DOE Project on Heavy Vehicle Aerodynamic Drag

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Objective

Class 8 tractor-trailers consume 11-12% of the total US petroleum use. At highway speeds, 65% of the energy expenditure for a Class 8 truck is used in overcoming aerodynamic drag. The project objective is to improve the fuel economy of Class 8 tractor-trailers by providing guidance on methods for reducing drag by at least 25%. This reduction in drag would represent a 12% improvement in fuel economy at highway speeds, equivalent to about 130 midsize tanker ships per year. The specific goals of this project include:

- ***In support of DOE's mission***, provide guidance to industry to improve the fuel economy of class 8 tractor-trailers through the use of aerodynamic drag reduction
- ***On behalf of DOE***, to expand and coordinate industry participation to achieve significant on-the-road fuel economy improvement
- ***Join with industry in getting devices on the road***
- ***Demonstrate*** new drag-reduction techniques and concepts through the use of virtual modeling and testing
- ***Perform full-scale wind tunnel validation of selected devices with industry collaboration and feedback***
- ***Establish a database*** of experimental, computational, and conceptual design information

Approach

- Apply computational fluid dynamics (CFD) tools to understand the aerodynamic flow around heavy vehicles in order to assess the design and performance of drag reduction devices
- Investigate the performance and optimization of aerodynamic drag reduction devices (e.g., base flaps, tractor-trailer gap stabilizers, underbody skirts, wedges and fairings, and blowing and acoustic devices, etc.)
- Provide industry with design guidance and insight into the performance of add-on devices utilizing both experimental and computational results
- Generate an experimental database to understand the accuracy of CFD results

- Provide industry with conceptual designs of drag reducing devices
- Join with industry to perform a full-scale wind tunnel validation test of candidate devices at the National Full-Scale Aerodynamics Complex (NFAC)

Accomplishments

For the fiscal year 2009, the DOE Heavy Vehicle Aerodynamics Drag Project has achieved two primary objectives. The first and foremost is the planning and preparation for the full-scale wind tunnel investigation of aerodynamic drag reduction devices that have shown significant drag reduction on the track or on the road. The study will be performed in the 80'×120' wind tunnel at NFAC, operated by the U.S. Air Force at NASA Ames Research Center (Figure 1). The anticipated start date for this test is mid-December 2009 for duration of two months. During this test, the performance of drag reducing add-on devices from six different commercial companies and a government laboratory will be assessed on combinations of two tractors (day-cab and sleeper-cab models) and four trailers. The commercial devices were selected based upon a number of criteria, such as prior fuel economy improvement data, weight penalty, level of driver intervention, cost, durability, and installation difficulty. The selected devices will target the vehicle underbody, tractor-trailer gap, and trailer base. In addition to the commercially available devices, a selected number of research devices will be evaluated during the wind tunnel study. CFD simulations have played a key role in the vehicle installation in the tunnel test section (Figures 2-3). In particular, we have investigated the sensitivity of the aerodynamic forces to the vehicle height above the tunnel floor and to minor changes in the vehicle yaw angle.

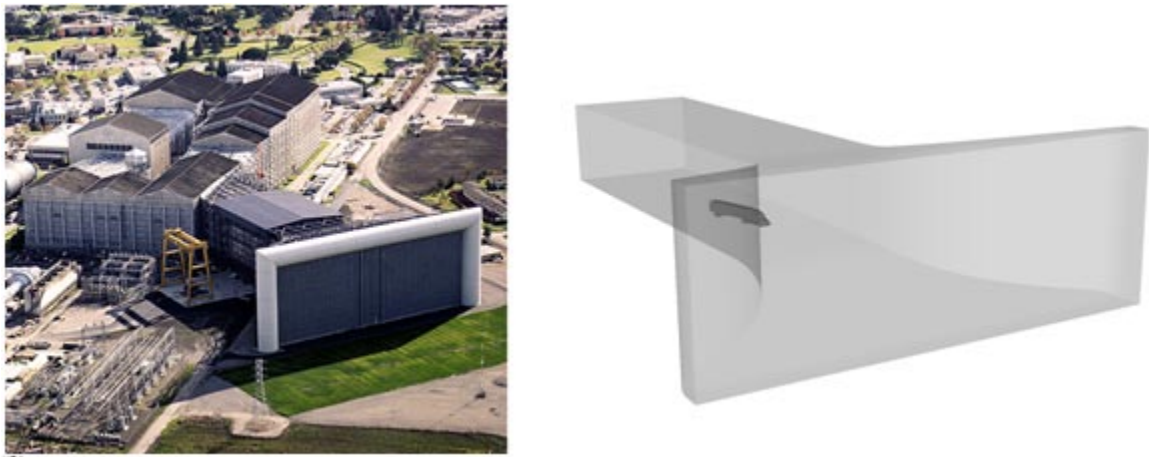


Figure 1. The National Full-scale Aerodynamic Complex (NFAC) 80'×120' wind tunnel at NASA Ames Center (left, actual; right, computational model).

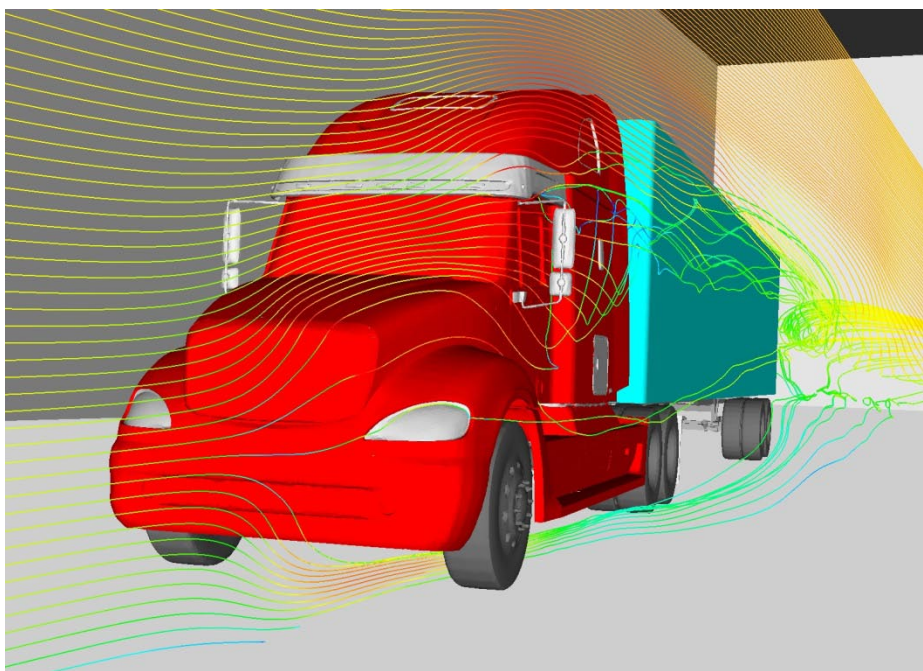


Figure 2. Velocity streamlines about a class 8 heavy vehicle at 6.1 degrees yaw angle in the 80'×120' wind tunnel (CFD simulation).

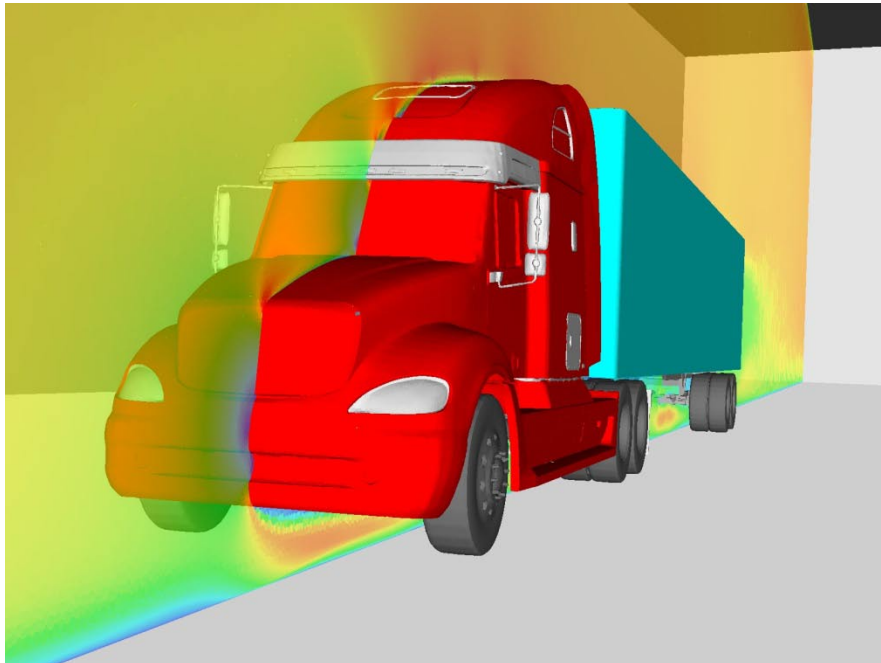


Figure 3. Velocity magnitude contours on a vertical cutting plane within the 80'×120' wind tunnel produced by a heavy vehicle at 6.1 degrees yaw angle (CFD simulation).

The second accomplishment is the preliminary investigation of tanker-trailer aerodynamics. Throughout the United States, there are approximately 200,000 tanker-trailers in operation. These vehicles are typically used to haul aluminum and petroleum, chemical, food-grade, and dry-bulk products¹. It is estimated that a 1% improvement in the fuel economy of tanker-trailers could result in an annual fuel savings of approximately 30×10^6 gallons throughout the United States. A review of the literature revealed that there have been relatively few studies on tanker-trailer aerodynamics. The first study that we know of occurred in 1978 and was a wind tunnel investigation of 1/10th scale dry and liquid cargo tankers². Due to the model scale and limitations on the maximum tunnel speed, the Reynolds number of the flow about the tanker model was about an order of magnitude less than that of a full-scale vehicle. Additionally, the authors only present drag coefficient data at 0° and 20° vehicle yaw angles. The next study in the literature does not appear until 2009, in which the authors investigate the aerodynamics of a full-scale tanker-trailer and a simplified tractor geometry using CFD simulations³. To reduce the computational resources, a symmetry boundary condition was employed along the vehicle centerline, thus limiting the study to a 0° vehicle yaw angle. Through various geometric modifications of the tanker-trailer, the authors report a reduction in the drag coefficient by 23%. To provide realistic data on a more representative tanker-trailer, we have begun to perform CFD simulations on a detailed day-cab tractor and tanker (Figure 4). The preliminary results of this study demonstrate that the full-scale vehicle has a drag coefficient of approximately 1.0 at highway speed within a typical crosswind. We will present this preliminary data in November 2009 at the annual American Physical Society Division of Fluid Dynamics conference.



Figure 4. Tanker-trailer geometry.

1. National Tank Truck Association, www.tanktruck.org
2. Weir, D.H., Strange, J.F., Heffley, R.K., 1978, Reduction of Adverse Aerodynamic Effects of Large Trucks, Report FHWA-RD-79-84.
3. Buil, R.M. & Herrer, L.C., 2009, Aerodynamic Analysis of a Vehicle Tanker, J. Fluids Eng., 131:041204-1-17.

Future Direction

- Complete the full-scale wind tunnel study at NFAC and document the results by generating internal documentations, conference publications, and presentations
- Utilize the data obtained from the wind tunnel study to down-select the drag reduction devices to be investigated in the Dept. of Energy grant, “Fleet Evaluation and Factory Installation of Aerodynamic Heavy Duty Truck Trailers” (DE-PS26-08NT01045-03), which will commence in FY10
- Begin a detailed investigation of the major aerodynamic drag sources on tanker trailers and design devices to mitigate these drag sources
- Partner with Navistar, Inc., in the SuperTruck Initiative

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